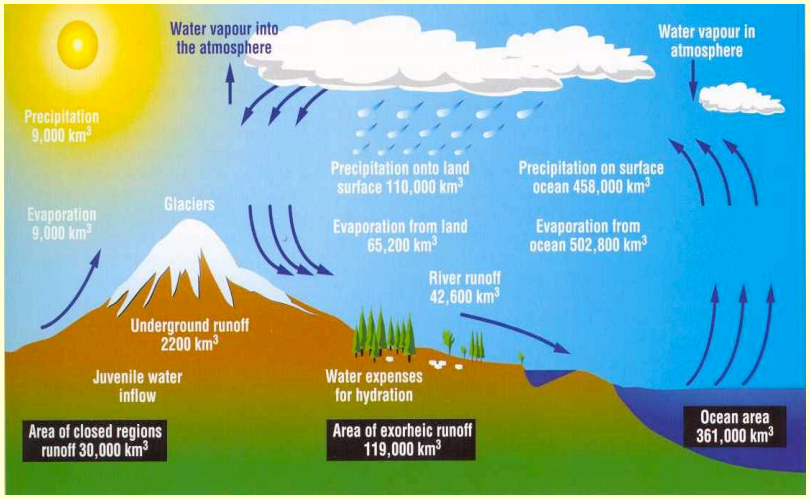
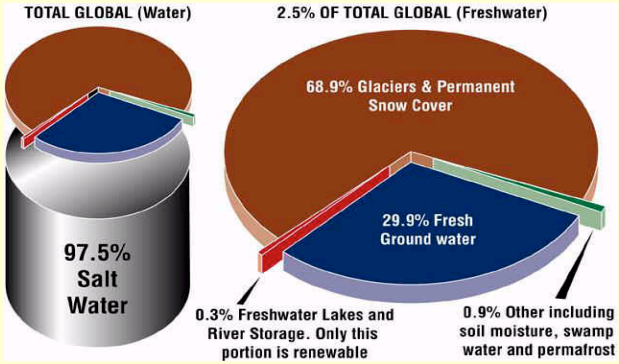
GPM and Societal Applications: A Generic Framework

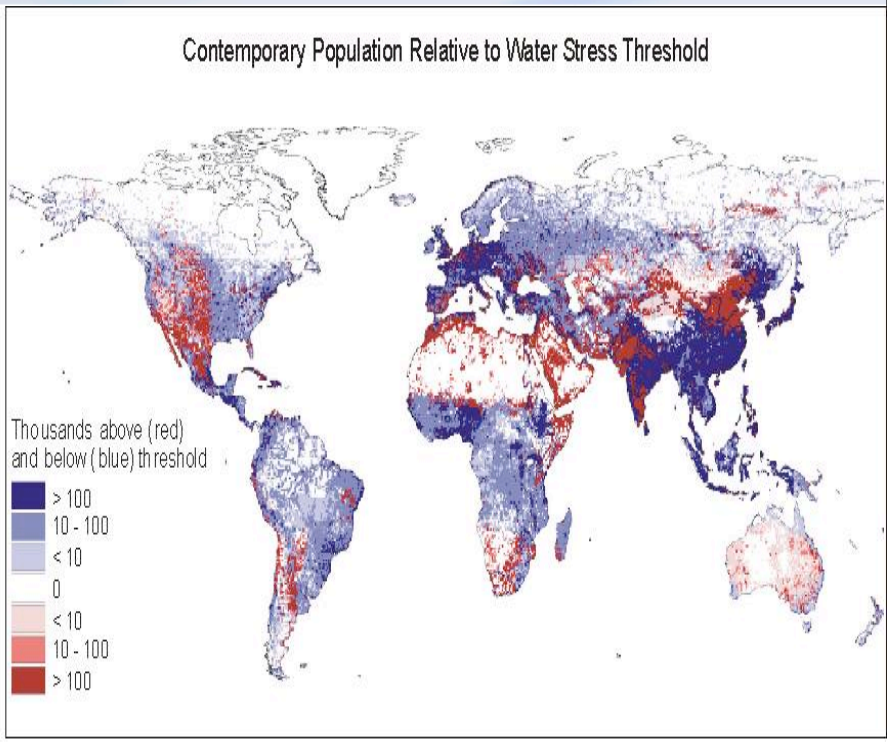




J. Marshall Shepherd, Ph.D
University of Georgia, Atmospheric Sciences Program
Department of Geography

"The Grim Arithmetic of Water"

The National Academy of Science recommends "that the GPM mission be launched without further delays, citing its international nature and the importance of understanding the availability of fresh water."



Copyright © 2000 *Science*

Weather, Climate, and Water Cycle Events Have Socio-Economic Implications

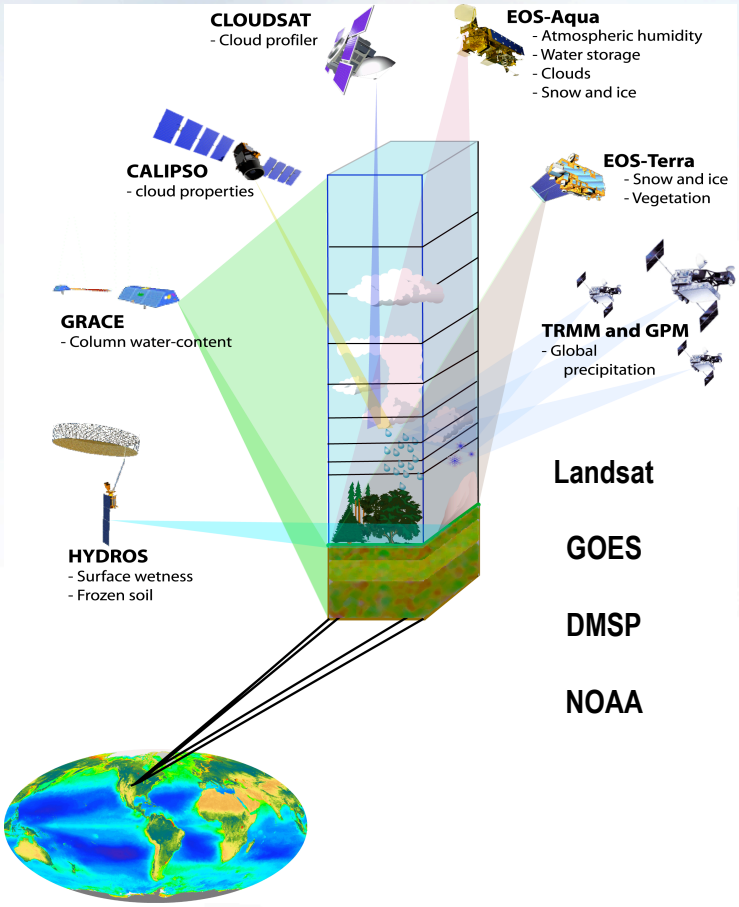


TABLE 1–1 Averages of Annual Fatalities and Financial Costs of Weather Events in the United States During the 1990s

EVENT	ANNUAL MEAN NUMBER OF FATALITIES	ANNUAL MEAN LOSS (ADJUSTED TO 1999 DOLLARS)
Floods	98	$5,300,000,000
Hurricanes	21	$5,400,000,000
Winter Storms	57	$329,000,000
Tornadoes	56	$777,000,000
Extreme Heat	282	$85,000,000
Extreme Cold	292	$368,000,000
Lightning	69	$38,000,000
Hail	1	$938,000,000
Total	876	$13,000,000,000

Source: Data from Pielke and Carbone, *Bulletin of American Meteorological Society,* March 2002.

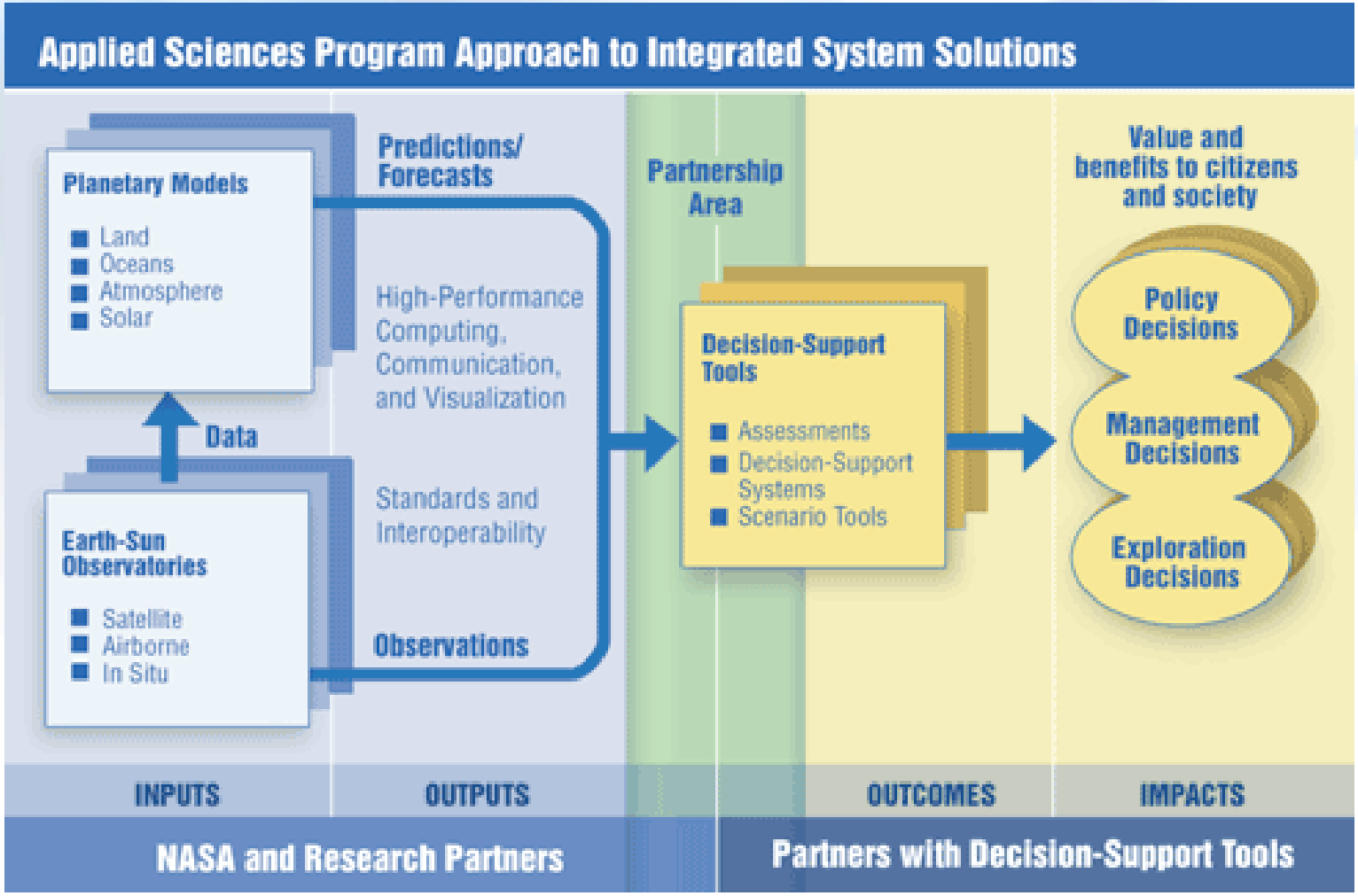
Copyright © 2007 Pearson Prentice Hall, Inc.

Domestic and International Drivers..

Domestic and International Committees as related to the NASA Science Focus Areas

	Domestic	International
Climate Change	Climate Change Science Program (CCSP) Climate Change Technology Program (CCTP)	Intergovernmental Panel on Climate Change (IPCC)
Weather	U.S. Weather Research Program (USWRP)	World Meteorological Organization (WMO)
Natural Hazards	Committee on Environment and Natural Resources (CENR) Subcommittee on Natural Disaster Reduction (SDNR)	International Strategy for Disaster Reduction (ISDR)
Sustainability	NAS Roundtable on Sustainability	World Summit on Sustainable Development (WSSD)
Earth Observation Systems	CENR Interagency Working Group on Earth Observations (IWGEO)	Group on Earth Observations

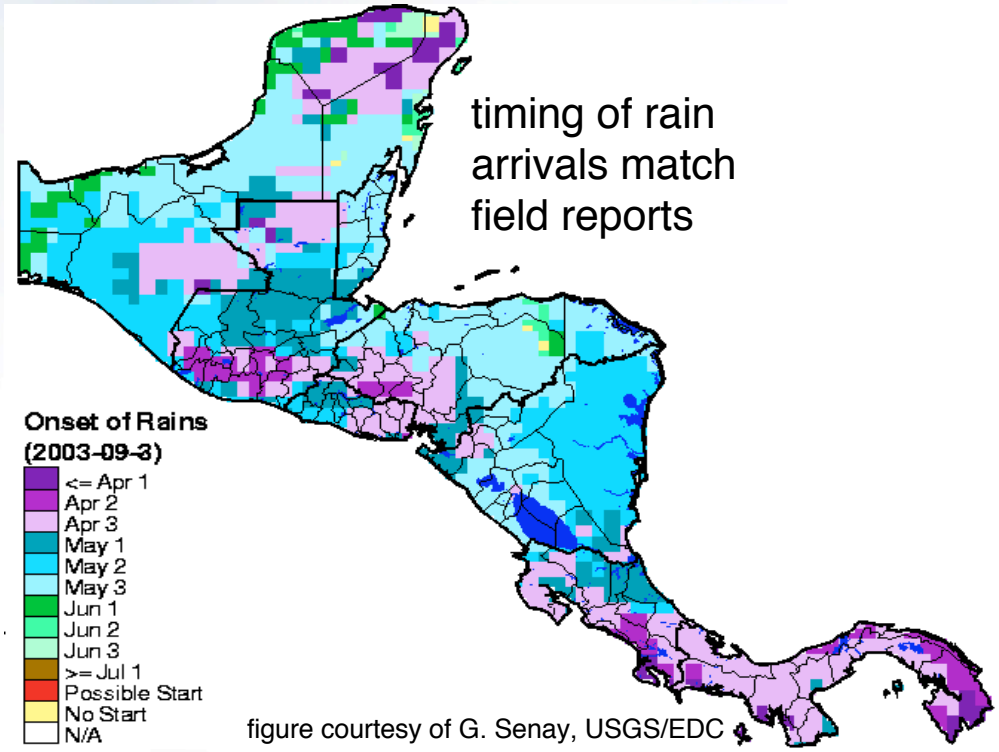
GPM and NASA Applied Science Approach



The University of Georgia

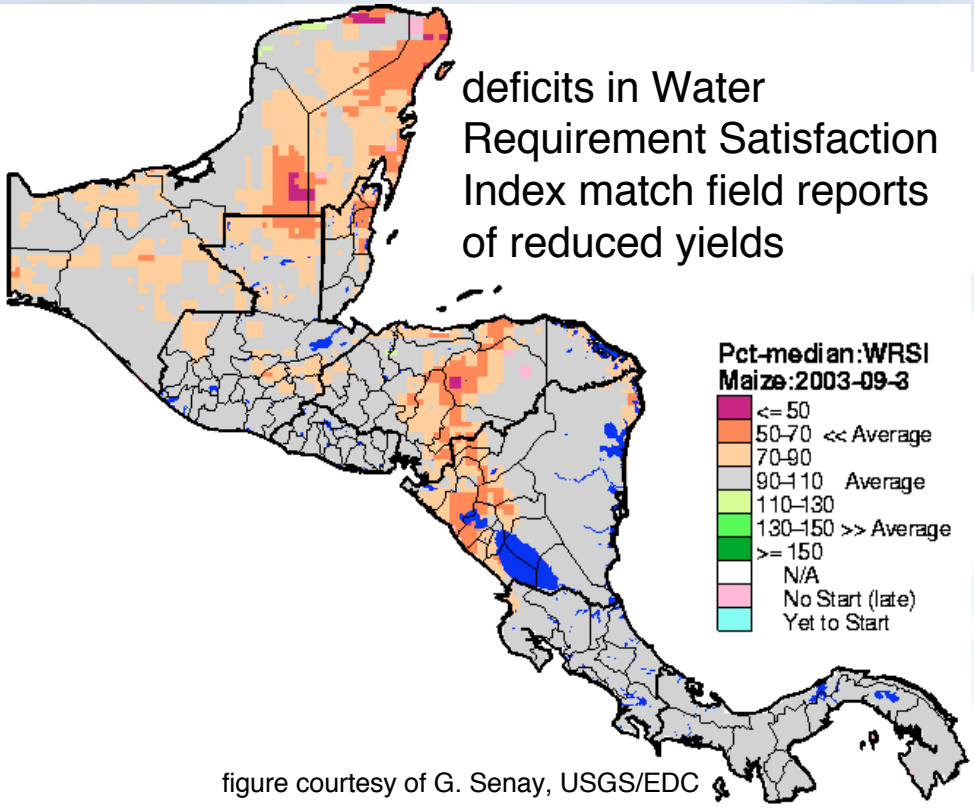
TRMM Data Used by USAID, USGS for Crop Forecasts

- the USAID Famine Early Warning System Network (USAID/FEWS-Net) is a joint program of DoS, USGS, NOAA
- goal is crop and weather assessment around the world



timing of rain arrivals match field reports

figure courtesy of G. Senay, USGS/EDC



deficits in Water Requirement Satisfaction Index match field reports of reduced yields

figure courtesy of G. Senay, USGS/EDC

- TRMM real-time Multi-Satellite Precipitation Analysis (MPA) tested in 2003; first results are promising
- MPA now in quasi-operational worldwide
- High Resolution, Multi-Satellite Products are increasingly being used for flood assessment
- Web-Based and National Warning Alert Systems are being developed for science and applications use (http://trmm.gsfc.nasa.gov and IFNet (Japan))
- Products may be valuable for warning and mitigations strategies

The University of Georgia

Partnerships in Applied Sciences

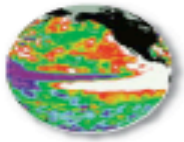
- Many National Applications Areas are Directly Relevant to GPM:

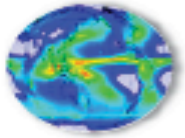
National Application	Partner Agencies	Decision Support Systems
Agricultural Efficiency	USDA, NOAA	CADRE - Crop Assessment Data Retrieval & Evaluation (USDA)
Air Quality	EPA, NOAA, USDA	CMAQ - Community Multi-scale Air Quality Modeling System AQI - Air Quality Index
Aviation	DOT/FAA, NOAA	NAS_AWRP - National Air Space - Aviation Weather Research Program
Carbon Management	USDA, DOE, NOAA	CQUEST-EA92-1605b - Energy Act of 1992, Section 1605b
Coastal Management	NOAA, EPA, NRL	HAB - Harmful Algal Bloom Bulletin / Mapping System CREWS - Coral Reef Early Warning System
Disaster Management	DHS/FEMA, NOAA, USGS, USFS	HAZUS-MH - Hazards US - Multi Hazards
Ecological Forecasting	USAID, NOAA, NPS, CCAD, USGS	SERVIR - Regional Visualization & Monitoring System
Energy Management	DOE, UNEP, NOAA, NRC	RETScreen - Energy Diversification Research Laboratory (CEDRL)
Homeland Security	DHS, USGS, NOAA, NIMA, DoD	IOF - Integrated Operations Facility
Invasive Species	USGS, USDA, NOAA	ISFS - Invasive Species Forecasting System
Public Health	NIH, CDC, DoD, EPA	PSS - Plague Surveillance System EPHTN - Environmental Public Health Tracking Network Program Research MMS - Malaria Monitoring & Surveillance RSVP - Rapid Syndrome Validation Project
Water Management	EPA, USDA, USGS, BoR	RiverWARE - Bureau of Reclamation Decision Support Tool AWARDS - Agricultural Water Resources & Decision Support Tool BASINS - Better Assessment Science Integrating Point & Non-point Source

GPM Objectives -Inherent Societal Benefit

Scientific Objectives:

Through more accurate, frequent (~3 hour), global, detailed measurements (i.e., in terms of resolution and physics) of precipitation, GPM will:





Water Cycle

Produce accurate representation of the water cycle and its key components like precipitation to enable more realistic diagnosis and prediction of Earth's water budget and related changes

Climate

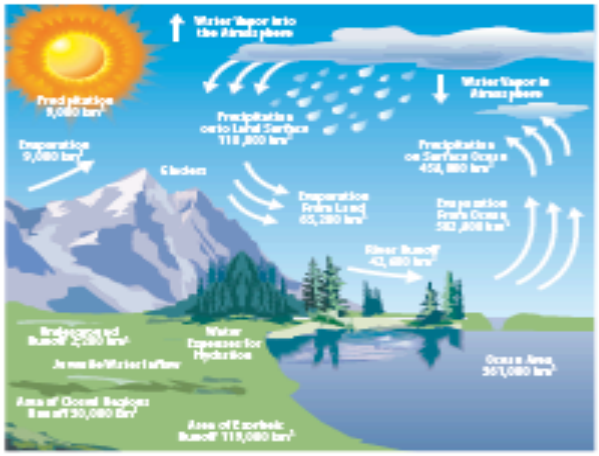
Establish a numerical relationship between global water cycle variability and global temperature change plus test the hypothesis that global warming accelerates the rate of water moving through Earth's system

Weather

Improve short to medium range weather forecasting and long-term climate simulations through improved integration of satellite precipitation data in computer model forecast systems

Hydrometeorological Applications

Improve predictions of floods, droughts, fresh water reserves, crop conditions, and other water-related applications



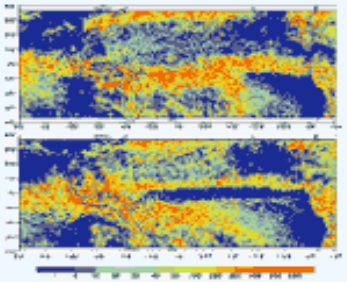
Precipitation links climate, weather, and surface water processes and is key to understanding how Earth's water cycle responds to their changes.

Global Precipitation Measurement Means Improvements In:

- Water Resource Management
- Agriculture
- Policy and Planning
- Transportation
- Forestry
- Natural Hazards Assessment
- Hydrology and Oceanography
- Weather Forecasting
- Homeland Security
- Energy Management
- Climate Change Assessment

The University of Georgia

JAXA's Perspective

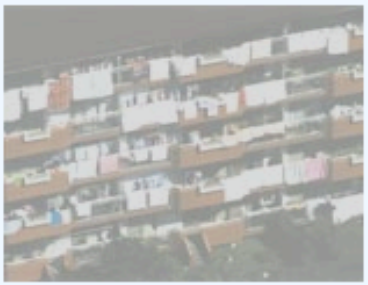


Land management
Water resource management
Storage control of dams
Natural hazards assessment

Earth environment research and environmental policies
Unusual weather event monitoring
Understanding of climate phenomena such as El Niño
Observation of changes due to global warming

Home use
Regional precipitation map
Typhoon/flood information

Data flow and utilization of GPM data



Meteorology
Improvement of weather forecasts
Providing near-realtime precipitation information
Prediction of typhoons and heavy rain

Agriculture and Fishery
Management of agriculture production and fish catches
Secure water for agriculture

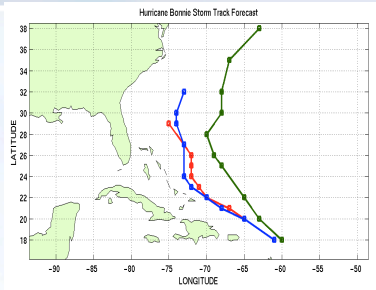
- http://www.eorc.jaxa.jp/GPM/index_e.htm

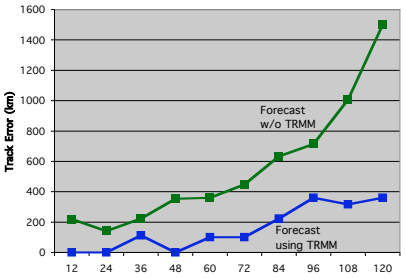
Effective usage of GPM data in applications - II

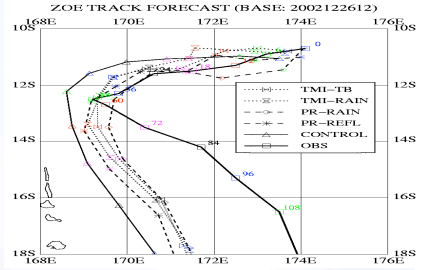
- Weather Forecasting, NWP, data assimilation, and reanlaysis:
  - Advanced assimilation methods to extract maximum information from precipitation data in the presence of forecast model errors
  - Improved understanding and modeling of precipitation error properties
  - Tropical Cyclone Assessment/Prediction
- Hydrological modeling & prediction:
  - Innovative hydrological modeling and prediction systems
  - Hydrometeorological testbeds for evaluating the quality of satellite precipitation products in hydrological applications
  - Improved techniques for merging high-resolution global precipitation products base on combined satellite and ground measurements
- Societal Applications Derived From Advances Above
  - Public Health
  - Agricultural Efficiency
  - Water Resource Management
  - Land Management/Planning
  - Homeland Security

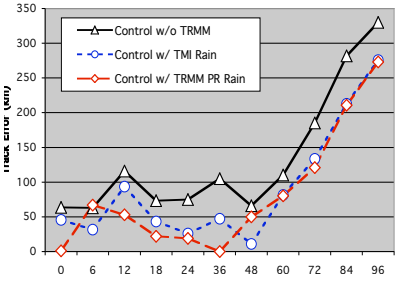
Improving weather forecasting through rainfall assimilation

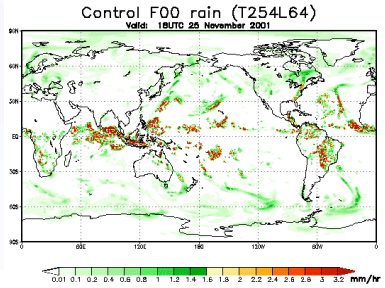
- **NASA/GSFC (*research*):**
  - **1D+3DVAR continuous rain assimilation (improved 5-day Bonnie forecast)**
- **ECMWF (*research, operational 2004*):**
  - **1D+4DVAR rain assimilation (improved 3-day Zoe forecast)**
- **NOAA/NCEP (*real-time operational*):**
  - **3DVAR rainfall assimilation (reduced over-prediction of tropical convection)**
- **FSU (*research, semi-operational*):**
  - **Multi-model super-ensemble forecast (improved hurricane precipitation forecast)**
- **JMA (*operational Oct. 2003*):**
  - **3D & 4DVAR rainfall assimilation**

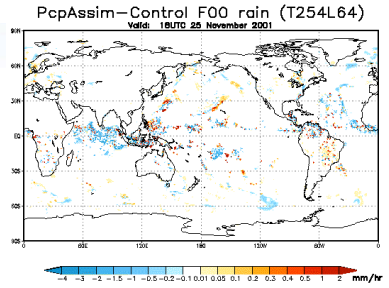




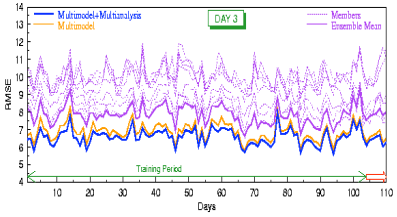








Superensemble : RMS Error of Global Precipitation (0°-360°E;90°S-90°N)



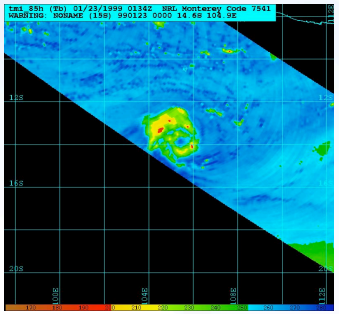
The University of Georgia

Effective usage of GPM data in applications -

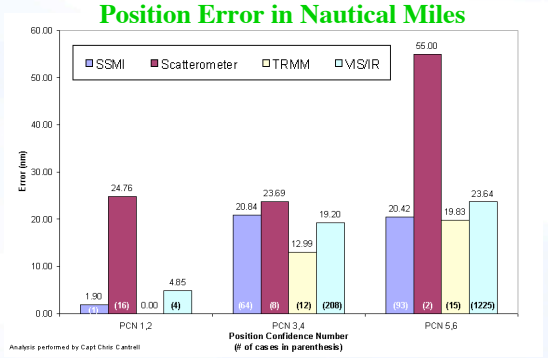
Lessons learned:

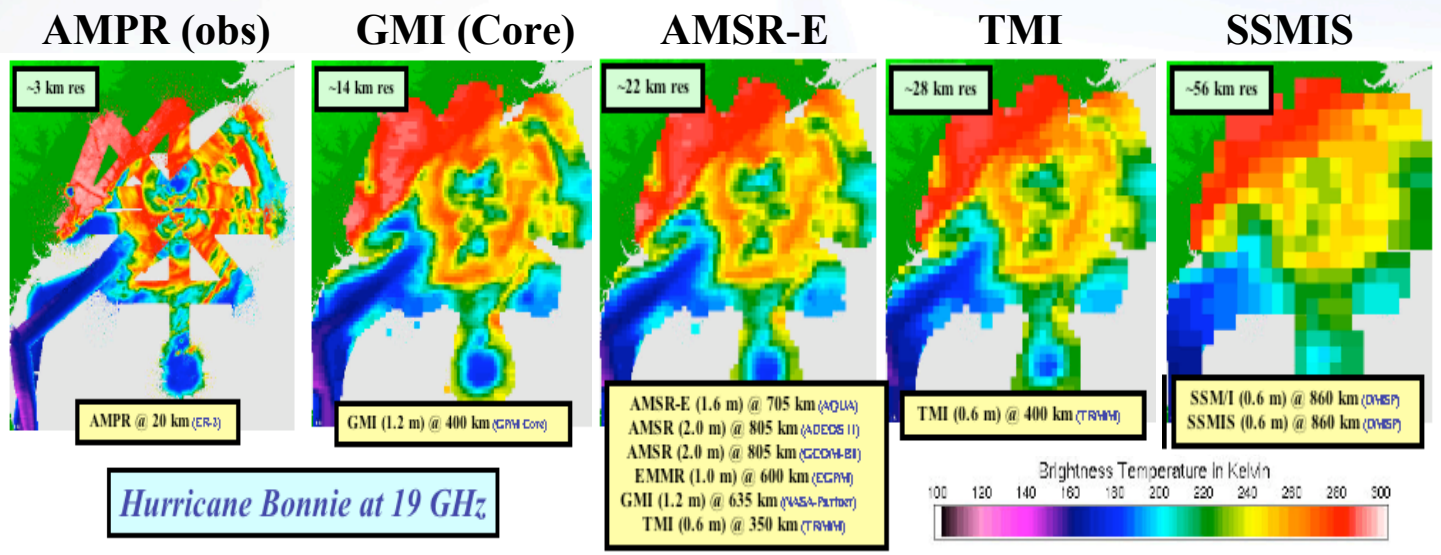
- Direct benefits of observations of precipitation intensity and structure
  - Monitoring extreme precipitation events and freshwater availability
  - Improving position fix for typhoon/hurricane predictions

Higher-resolution GPM radiometer data can provide better position fixes in early stages of storm development



TMI 85GHz Image of enclosed eye with spiral bands





Hurricane Bonnie at 19 GHz

The University of Georgia

Case Study: NOAA – Weather & Water

Goal	**Goal 3. Weather & Water** Increased accuracy and lead time of warning and forecasts	
Program	**Global Satellite Precipitation Program** Improved rainfall forecasts in excessive rainfall events from xx mm/day to yy mm/day.	*Indicator: Forecast accuracy for rainfall > 25 mm/day* *Unit of Measure: mm/day* *Baseline: xx mm/day (2003)* *Target: yy mm/day (2010)*
Component	**Monitor and Observe Component** Develop global, ≤3 hourly satellite retrievals (visible, IR, passive MW, active MW?, with 15-minute data latency	*Indicator: Satellite observations* *Unit of Measure: global #/3-hours* *Baseline: xx/3-hours (2003)* *Target: yy/3-hours (2010)*
Activity	**Real-time Product Generation Activity** Increase the number of global, real-time precipitation rate retrievals from xx (2003) to yy (2010)	*Indicator: # precipitation retrievals* *Unit of Measure: global #* *Baseline: xx (2003)* *Target: yy (2010)*

Operational and "Human Scale" Applications Stakeholder (NOAA, USDA, Water Resource Agencies, etc.) Requirements are Driving the Need for Better Precipitation Estimates

Application	Timeliness (measurement to user)	Temporal Resolution	Spatial Resolution	Spatial Domain
Flash Floods	≤5 min	≤15 min	≤4 km	CONUS/Land
TRAP	0.5 – 1.5 hr	1-3 hr	≤15 km	Global
Rainfall potential	0.5 – 1.5 hr	1-3 hr	≤15 km	Global
NWP Assimilation	0.5 – 1.5 hr	1-3 hr	≤15 km	Regional & global
Solid Precipitation	0.5 – 1.5 hr	1-3 hr	≤15 km	Regional & global
Climate Monitoring	Daily	3 hr	≤25 km	Global
Soil moisture and wetness	Daily	12 hr	≤25 km	Regional & global land

--Source: NOAA@GPM Applications Workshop 2002

versity of Georgia

Considerations As We Approach GPM

- Improved understanding of the “science” of calibration/merging/blending issues
- Leverage all products: *gauge, radar, and satellite* to produce an optimal global rain map for applications

---->must approach scales of the user community for global use)

- Satellite-based flood products must leverage ancillary data and systems (LDAS, soil moisture, model-predicted precipitation)
- uncertainty characterization (e.g. rain detection error, bias, and spatial structure of random error) of instantaneous microwave precipitation
- Precipitation type information to distinguish rain from frozen precipitation
- Cold Season/Climate Applications
- GIS standards or interfaces/Others??
- Develop similar “NOAA Model” with other Domestic/International Agencies